# ACIDIC PRECIPITATION IN ONTARIO STUDY

## (A.P.I.O.S.)

Summary of Research Results and

List of Publications

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Muskoka Conference '85

September 15 - 20, 1985


For further information and/or reports:

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# ACIDIC PRECIPITATION IN ONTARIO STUDY

## (A.P.I.O.S.)

Historically, Environment Ontario and other North American environmental agencies have been dealing with contaminants as pollutants in their own right, concerned with their potential "localized" and "community" effects.

However, acidic precipitation studies to date have demonstrated that the precursors, $SO_2$, sulphates, and nitrates, are from sources which, in many cases, are distant from the sensitive receptor lakes. The severity of this problem of long range transport of air pollutants into Ontario became apparent to Ontario scientists when they began to analyze the results from several special studies, in particular, the Sudbury Environmental and Lakeshore Capacity Studies. Both of these geographically intensive programs measured atmospheric pollutants and quantified the proportion which, as a consequence of various physical and chemical means, ultimately end up in sensitive terrestrial and aquatic ecosystems.

In particular, these studies indicated that, when using contemporary monitoring and analytical techniques, the secondary or evolutionary pollutants associated with primary emissions of particulates and $SO_2$ were being deposited in large measure by the rain falling over extensive portions of the province with adverse effects on Ontario's very sensitive environment.

In response to the seriousness of this situation and recognizing its similarity with the Scandinavian problem, the Ontario Government initiated a major long range transport of atmospheric pollutants or "acidic precipitation" program in 1979.

The overall mandate of the program is "to protect Ontario's environment from the detrimental effects of acid precipitation and other air pollutants subject to long-range transport".

Because of the extensive environmental effects associated with the acid rain problem, Ontario's A.P.I.O.S. research program involves the participation of several provincial Ministries, with the Ministry of the Environment in the lead role. The Ministry of Natural Resources is cooperating extensively in the studies of fisheries and forestry effects.

The results of our scientific research to date include the following:

Atmospheric Processes Studies

° A sulphate wet deposition rate of 20 kg $ha^{-1}$ $yr^{-1}$ is currently exceeded in all of central and southern Ontario. The observed deposition pattern, with high values in the southern portion of the province, when merged with other Eastern North American data, suggests that the responsible emission source area is the northeastern U.S.A.

° On a province-wide basis, the annual dry deposition rate of sulphur is approximately one-quarter of the wet deposition rate, although in the southernmost portions of the province, the importance of sulphur dry deposition is greater (being about 50% of the wet deposition). Again, the air concentration and dry deposition pattern indicate a source area to the south of Ontario.

° The contribution of nitrates to acid loadings in the province is comparable to that of sulphates.

° The largest source area in the province - the nickel smelters at Sudbury - contributes a relatively small portion of the total atmospheric deposition of acidity and sulphates. Thus, control of the Sudbury smelters alone will result in only slight decreases in deposition at receptors in Ontario. Meteorological analysis indicates, for example, that the Sudbury contribution is about 15% or less of the total for wet deposition and 40% or less for dry deposition of sulphur oxides in Ontario.

° Much of the atmospheric deposition of acidifying substances is due to sources to the south of the province. The highest sulphate wet deposition at receptors in southern Ontario near the Canada-U.S. border (more than one-half the total), for example, is associated with air parcels coming from the direction of high emission density areas in Indiana, Ohio and Pennsylvania. At these receptors, sulphate wet deposition attributable to Ontario sources is 14% or less.

° Statistical and trajectory mathematical models describing long-range transport and acidic deposition have been completed and peer-reviewed and extensively applied in control strategy studies by the Ministry of the Environment. The models indicate that contribution of U.S. sources to wet sulphur deposition at Muskoka and southern Québec are 50% and 30% respectively.

° Model results indicate that reducing $SO_2$ from Canadian sources alone will not enable us to meet the target of 20 kg/ha·yr of wet sulphate deposition at all sensitive

receptors in Canada. U.S. $SO_2$ sources also need to be controlled if this target is to be met at all sensitive receptors in Canada.

Aquatic Effects Studies

° In central Ontario, acidic deposition derived from anthropogenic $SO_2$ emissions is the primary causal factor in recent lake acidification and a reduction in the anthropogenic emissions affecting this area will result in a decrease in lake acidity.

° Although there are few acidic lakes (i.e. alkalinity $< 0$) outside of the Sudbury region, there are a great number of very sensitive lakes and streams throughout the Precambrian part of southern Ontario.

° Short-term acidification (that is, the reversible loss of alkalinity resulting from episodes or events such as snowmelt or storms) is a commonplace occurrence in the Precambrian part of southern Ontario. After natural dilution is accounted for, sulphuric acid is usually the major cause of short-term acidification, although nitric acid is, in a few isolated cases, more important. Springtime pH depressions associated with snowmelt effects are very widespread in Ontario.

° Long-term acidification (that is, the gradual decline in alkalinity measured on an annual basis) is occurring very slowly with little or no measurable change observed in lakes and streams studied over five to nine years. The time-scale for acidification can probably be measured in decades.

° Sulphate has become the dominant anion in almost all waters in Precambrian southern Ontario.

° Reductions in lake acidity follow reductions in $SO_2$ emissions within a short time frame.

° Organic acids contribute to the acidity of some lakes and streams but do not contribute significantly to short-term acidification and are not, in general, a major factor in the acidification process.

° In addition to strong acids, substantial amounts of trace metals are supplied to lakes and catchments via long-range atmospheric transport. Lead, cadmium and zinc are of particular concern, with most lead of anthropogenic origin (fuel combustion) averaging about 700 kg $km^{-2}$ over southern Ontario. Total lead fluxes are 100 to 500 times greater than natural fluxes.

° In a survey of approximately 4,500 Ontario lakes, it was found that 4.2% were acidified (alkalinity $< 0\ \mu eqL^{-1}$) and a

further 16.7% were extremely sensitive to acidic deposition (alkalinity $> 0$ $\mu eqL^{-1}$ and $< 40$ $\mu eqL^{-1}$).

° The effects of acidification on aquatic biota are primarily a result of the toxic effects of hydrogen ion and inorganic monomeric aluminum.

° Early life stages of several amphibians are affected by $H^+$/Al concentrations that are observed in many lakes, streams and ponds.

° There are no apparent effects of acidification on either the zooplankton or macrophyte populations of lakes other than those in the Sudbury area. Some benthic stream invertebrates (mayflies, chironomids) are affected by observed $H^+$/Al levels, while others (caddisflies, blackflies) are not.

° Phytoplankton community structure is very different in acidic lakes (i.e. a much higher proportion of dinoflagellates which are not likely very food-chain functional). Phytoplankton biomass is not altered directly by acidification but may be indirectly affected by nutrient availability.

° Among phytoplankton species showing different pH and alkalinity tolerances are many species of diatoms and scaled chrysophytes whose identifiable remains are "preserved" in lake sediment. These methods are being worked out with application to a large calibration lake set (55 lakes). Application to cores from selected lakes is planned to determine rate of change of lakewater acidity.

° The odour producing species Chrysochromulina breviturrita has been shown in field and laboratory studies to grow well over a pH range of 4.5 to 6.9. This species has also been shown to have an unusually high selenium requirement. The hypothesis is that blooms will occur in low pH lakes receiving adequate supplies of selenium and sulphate (Se and S are chemical analogues).

° Some species of filamentous algae forming large masses in shoreline areas of lakes have been shown in laboratory and field studies to grow best at low pH. Although data are still preliminary, growth appears to be enhanced by acidification and reversed by neutralization.

° The sensitivity of the major species of fish in southern Ontario waters to strong acid and aluminum follows the sequence: common shiner > white sucker > walleye > lake whitefish > lake trout > smallmouth bass > brook trout. The first five of these species are affected in the laboratory at concentrations that are observed in lakes and streams.

° In Ontario, both habitat and fish communities have been lost near point source emissions such as Sudbury and Wawa.

° Recent improvements in water chemistry coincident with the reduction of emissions from Sudbury area smelters and the resumption of recruitment by some fishes indicate that habitat losses can be reversed if emissions are reduced.

° In a survey of approximately 55% of Ontario's 2,218 lake trout lakes, it was found that 6% were acidified (alkalinity $< 0\ \mu eqL^{-1}$) and 6.3% had pH levels $< 5.5$, a level of pH below which lake trout populations do not recruit successfully.

° Fish species richness (as species number) was found to decline with decreasing pH from pH 6.3. Thirty and one half percent of all lakes sampled have pH $< 6.3$ and hence may be limited in species richness by acidity.

° Ground waters from some domestic wells completed in sands and gravel are acidic. This acidity is caused by dissolved $CO_2$ and not by acidic precipitation.

° The residence time and flow path of water in the ground influence the acidity of the water. In the calibrated watersheds, deep ground waters that have passed through the deeper geologic zones are buffered better than shallow ground waters.

° Application of limestone or limestone slurry is an effective and cost efficient method of neutralizing lakes affected by acidic precipitation.

° Neutralization of two study lakes to alkalinities typical of many shield lakes did not cause adverse impacts on benthic or fish communities.

Terrestrial Effects Studies

° The results of simulated acid rain experiments with agricultural crops illustrate that plant response to simulated acid rain treatments is not only species dependent but also strongly cultivar dependent. Rainfall pH between 3.0 and 4.2 may have a negative effect, a positive effect or no effect on plant growth. Results have also indicated that plant response to simulated acid rain treatments is dependent on several factors:

a) rain characteristics (treatment application rate and duration of event);
b) disease and pests;
c) environmental conditions (high temperature, drought); and
d) interactive stress from air pollutants (ozone, sulphur dioxide and nitrogen oxides).

- The chemistry of lichen and moss tissue is influenced by regional pollution and contaminant sources as well as by long range transport associated with acidic deposition.

- There are elevated sulphur levels in lichen and moss tissue in southern Ontario. There is also a paucity of lichens in southern Ontario which can be ascribed to pollution and habitat disturbance.

- Naturally acidic soils (i.e. podzolic) are not as susceptible to changes in pH as less acidic soils such as brunisols.

- Acidic soils with a pH below 4.2 are subject to aluminum solubilization.

- Podzolic soils treated with acid rain simulants tend to adsorb added sulphate and nitrate becomes the mobile anion in leachates. Conversely, in natural forest soil systems, nitrate tends to be conserved in the soil and sulphate becomes mobile in drainage waters.

- Base cation content and carbonates are the most important chemical parameters when assessing soil sensitivity. Depth and texture are the most important physical parameters which determine the contact time between percolate and soil particles. Retention soil moisture within the soil matrix determines the degree to which chemical exchange between soil and water can occur.

- Throughfall is enriched in nutrient and trace elements as compared to incident precipitation. Enrichment of $SO_4^=$ under conifers is greater than under hardwoods under similar atmospheric deposition. Enrichment of $SO_4^=$ in throughfall is higher in areas of higher atmospheric deposition.

- Conifers, as a rule, induce a pH depression of throughfall water while hardwood species elevate the pH. These changes are on the order of a tenth of a pH unit.

- Shrubs contribute significantly more to the alteration of throughfall water, amplifying the role of the tree canopy in precipitation alteration.

- Stemflow is even more enriched in nutrient ions and trace elements. As with throughfall, the species of the tree bole has an influence on the degree of this enrichment. Stemflow differences between conifers and hardwoods are highly pronounced. Conifer boles can depress incident precipitation pH by one half to one full pH unit. Hardwood boles have the opposite effect.

- Nitrogen compounds tend to be conserved by the tree canopy and bole, the reverse trend of other nutrient ions.

- Soil leachate sampled at various horizons in a podzolic soil is more acidic (lower pH) than soil leachate from a brunisolic soil. Also, concentrations of $SO_4^=$ and Al in the podzolic soil leachate are higher.

- Sulphate concentrations in soil leachate are elevated following rain episodes which follow prolonged dry periods, possibly resulting from sulphur oxidation in the soil during the dry period.

- Nitrate in soil leachate is only detectable in the early spring or late fall, corresponding to tree dormancy periods. Therefore, nitrate is not an important mobile anion during the growing season.

- Despite weight losses due to decomposition of leaf litter, contents of N and K are elevated in decomposition litter bags. Presumably, such gain is due to microbial immobilization and/or adsorption at exchange sites.

- The current outbreak of sugar maple decline in the Muskoka area first became evident about 1978.

- Although some degree of decline was observed on maples in all age classes, it was most pronounced on older trees and trees which had been tapped for maple syrup production or otherwise wounded.

- Site nutrient deficiencies were not implicated in the decline of sugar maple.

- The soil at the Muskoka sugar maple sites was acidic and contained high amounts of soluble aluminum.

- Declining sugar maple trees in Muskoka suffered extensive root death and the fine roots had significantly higher aluminum concentrations than fine roots of healthy trees.

- A foliar chemical gradient was detected with reduced elemental concentrations in the tops of the tree crowns at Muskoka.

- Annual growth rings for both healthy and declining sugar maple trees were very narrow during two years of forest tent caterpillar defoliation.

- Subsequent to the collapse from the insect epidemic, growth recovered in the healthy trees but not in the declining trees.

- Incremental growth in the declining tree population appeared to be falling relative to the healthy trees for 20 years prior to caterpillar infestation.

- Early season droughts during the two years of insect defoliation (1976 and 1977) and again in 1983 and root infections by Armillaria mellea were some of the contributing factors to the tree decline.

- Acidic precipitation is considered to be an additional stress to the severe insect attacks and the spring droughts. Armillaria mellea root rot, tree age and site management are also contributing factors.

## A.P.I.O.S. RELATED TECHNICAL REPORTS AND SUBMISSIONS

### 1985

Air Concentration and Dry Deposition Fields of Pollutants in Ontario, 1982. APIOS Report No. 001/85.

Annual Statistics of Concentration and Deposition - Cumulative Precipitation Sites in Industrial/Urban Areas in Ontario, 1981 and 1982. APIOS Report No. 005/85.

Bryophyte Floras of Acid-Sensitive Lakes in South-Central Ontario: Description and Mechanisms of Sphagnum Invasion. G.C. Manville and N.D. Yan. APIOS Report (in press).

Cumulative (28 Day) Precipitation Chemistry Listings of Sites in Industrial/Urban Areas in Ontario, September 1980 - January 1983. APIOS Report No. 003/85.

The Morphometry and Geology of Plastic and Heney Lakes and Their Catchments. R. Girard, R.A. Reid and W.R. Snyder. Ont. Min. Envir. Data Report DR 85/1.

1983 Daily Precipitation Chemistry Listings. APIOS Report No. 004/85.

Ontario Soil Baseline Survey Analytical Data 1980/81. APIOS Report No. 002/85. Three Volumes.

Quality Assurance Manual. Acidic Precipitation in Ontario Study (APIOS) Deposition Monitoring Networks. APIOS Report No. 006/85. February 1985.

Temperature and Oxygen Data for the Muskoka-Haliburton Study Lakes (1983-1984). R.A. Reid and R. Girard. Ont. Min. Envir. Data Report DR 85/2.

Temperature, Oxygen, pH and Dissolved Inorganic Carbon Data Summary For Eight Lakes in the Muskoka-Haliburton Study Area (1982-1984). R. Girard and R.A. Reid. Ont. Min. Envir. Data Report 85/3.

### 1984

An Analysis of the Effects of the Sudbury Emissions Sources on Wet and Dry Deposition in Ontario. A.J.S. Tang and W.H. Chan. APIOS Report No. 011/84.

Annual Program Report - Fiscal Year 1982/1983. APIOS Report No. 001/84.

Annual Program Report - Fiscal Year 1983/1984. APIOS Report No. 010/84.

1984 (continued)

Annual Statistics of Concentration, Cumulative Ambient Air Monitoring Network, 1982. APIOS Report No. 015/84.

Annual Statistics of Concentration and Deposition - Cumulative Precipitation Monitoring Network, 1982. APIOS Report No. 008/84.

Annual Statistics of Concentration and Deposition - Daily Precipitation and Air Monitoring Network, 1982. APIOS Report No. 009/84.

Cumulative Ambient Air Concentration Listings August 31, 1981 - January 4, 1983. APIOS Report No. 013/84.

Cumulative (28 Day) Precipitation Chemistry Listings - January 5, 1982 - January 4, 1983. APIOS Report No. 003/84.

The Economics of Acid Precipitation: A Review of Socio-Economic Methods to Assess Acid Deposition Effects. APIOS Report No. 006/84. April, 1984.

Emission Inventory of Ontario and Eastern North America during 1980-1983 with Emphasis on the Sudbury Shut-down Period. D. Yap. APIOS Report No. 016/84.

Examination of Monthly Wet Sulphate Deposition by a Lagrangian Model and its Application to Study the Effects of Source Control on Receptors. G. Ellenton and P.K. Misra. APIOS Report No. 018/84.

Macrophyte Data from 46 Southern Ontario Soft Water Lakes of Varying pH. G.G. Hitchin, I. Wile, G.E. Miller and N.D. Yan. Ont. Min. Envir. Data Report DR 84/2.

Meteorological Studies to Quantify the Effects of Sudbury Emissions on Precipitation Quality and Air Quality During 1980-1983 with Emphasis on the Shut-down period. J. Kurtz and D. Yap. APIOS Report No. 017/84.

1982 Daily Ambient Air Concentration Listings. APIOS Report No. 004/84.

1982 Daily Precipitation Chemistry Listings. APIOS Report No. 002/84.

An Overview of the Cumulative Wet/Dry Deposition Network. APIOS Report No. 007/84.

An Overview: The Cumulative Wet/Dry Deposition Network. W.H. Chan, D.B. Orr and R.J. Vet. APIOS Report No. 005/84.

1984 (continued)

Physical and Chemical Data Summary for Twelve Selected Lakes in the Muskoka-Haliburton Area (1981-1983). R.A. Reid, B.A. Locke, G.E. Girard and A.C. Nicolls. Ont. Min. Envir. Data Report DR 84/1.

Precipitation Concentration and Wet Deposition Fields of Pollutants in Ontario, 1982. APIOS Report No. 012/84.

Quality Assurance Plan - APIOS Deposition Monitoring Program.

Summary: Source Apportionment Analysis of Air and Precipitation Data to Determine Contribution of the Sudbury Smelters to Atmospheric Deposition in Ontario. M.A. Lusis. APIOS Report No. 019/84.

1983

Acid Sensitivity Survey of Lakes in Ontario. APIOS Report No. 001/83.

Acidic Precipitation in Ontario Study - Technical and Operating Manual, APIOS Deposition Monitoring Program. W.S. Bardswick. April 1983.

Annual Statistics of Concentration and Deposition - Cumulative Precipitation Monitoring Network, 1981. R.W. Kirk. August 1983. APIOS Report No. 008/83.

Annual Statistics of Concentration and Deposition - Daily Ambient Air Monitoring Network, 1981. R.W. Kirk. September 1983.

APIOS Daily Precipitation Chemistry Listings, July 15, 1980 - December 31, 1981. Revised Edition January 1983.

APIOS Monthly/28 Day Cumulative Precipitation Chemistry Listings, June 1980 - December 1981. March 1983.

Area Source Emission Inventory for Nitrogen Oxides in Ontario by Ontario Research Foundation for MOE. Final Report (Proposal No. p-4261/G). September 1983.

Crustacean Zooplankton Communities of the Muskoka-Haliburton Study Lakes: Methods and 1976-1979 Data. G.G. Hitchin and N.D. Yan. Ont. Min. Envir. Data Report DR 83/9.

Daily Ambient Air Concentration Listings, July 25, 1980 - December 31, 1981. May 1983.

Depth and Volume of Strata in the Muskoka-Haliburton Study Lakes (1976-1982). R. Girard, B.A. Locke and R.A. Reid. Ont. Min. Envir. Data Report DR 83/10.

1983 (continued)

Geology and Geochemistry of the Muskoka-Haliburton Study Area. D.S. Jeffries and W.R. Snyder. Ont. Min. Envir. Data Report DR 83/2.

Hydrological Data for Lakes and Watersheds in the Muskoka-Haliburton Study Area (1976-1980). W.A. Scheider, C.M. Cox and L.D. Scott. Ont. Min. Envir. Data Report DR 83/6.

The Macrophyte Flora of 46 Acidified and Acid Sensitive Soft Water Lakes in Ontario. I. Wile and G. Miller. Ont. Min. Env. Tech. Rep.

Meteorological Analysis of Precipitation Event Sampling Data (July 1980 - December 1981). J. Kurtz. June 1983.

Morphometry of the Muskoka-Haliburton Study Lakes. A. Nicholls, R. Reid and R. Girard. Ont. Min. Envir. Data Report DR 83/3.

1981 Summary Statistics of Observed Concentration and Deposition: Daily Precipitation Monitoring Network. R.W. Kirk and W.H. Chan. June 1983.

Oxygen Profiles on the Muskoka-Haliburton Study Lakes (1976-1982). R.A. Reid, R. Girard and B.A. Locke. Ont. Min. Envir. Data Report DR 83/5.

A Performance and Systems Audit of the Acidic Precipitation in Ontario Study Monitoring Networks, Volume 1 and Volume 2 (Appendices). Submitted by Concord Scientific Corporation. ARB-69-83-ARSP. 1983.

Phytoplankton of Lakes in the Muskoka-Haliburton Area. L. Nakomoto, L. Heintsch and A. Nicholls. Ont. Min. Envir. Data Report DR 83/8.

Precipitation Concentration and Wet Deposition Fields of Pollutants in Ontario, September 1980 to December 1981. W.H. Chan, A.J.S. Tang and M.A. Lusis. June 1983.

A Preliminary Study for the Compilation of a VOC Emission Inventory for the Province of Ontario by Concord Scientific Corporation for MOE. Final Report CSC 110.260. June 1983.

Procedures Manual - Terrestrial Effects. H.D. Griffin (Ed.). APIOS Report No. 007/83.

The Province of Ontario. Presentation to the Michigan Air Pollution Control Commission in Opposition to the Consumers Power Company Request to Delay Bringing its J.H. Campbell and B.C. Cobb Power Plants into Compliance with the Michigan "One Percent or Equivalent Sulphur in Fuel" Rule. Grand Haven, Michigan. November 28, 1983.

1983 (continued)

Sediment Chemistry of Lakes in the Muskoka-Haliburton Study Area. P.J. Smith. Ont. Min. Envir. Data Report DR 83/7.

Studies of Lakes and Streams: Pukaskwa National Park. J. Sutton, L. Maki, K.J. Deacon and G.W. Ozburn. API 003/83.

Studies of Lakes and Watersheds in Muskoka-Haliburton, Ontario: Methodology (1976-1982). W.A. Scheider, R.A. Reid, B.A. Locke and L.D. Scott. Ont. Min. Envir. Data Report DR 83/1.

Temperature Profiles on the Muskoka-Haliburton Study Lakes (1976-1982). R.A. Reid, B. Locke and R. Girard. Ont. Min. Envir. Data Report DR 83/4.

Total Phosphorus and Major Ion Mass Balances for Lakes in the Muskoka-Haliburton Study Area (1976-1980). P.J. Dillon and W.A. Scheider. Ont. Min. Envir. Data Report DR 83/11.

Water Quality-Crustacean Plankton Relationships in Northeastern Ontario Lakes. W. Keller and J.R. Pitblado. API 002/83.

1982

Acid Sensitivity Survey of Lakes in Ontario. APIOS 003/82. Summer 1982.

The Case Against the Rain: A Report on Acidic Precipitation and Ontario Programs for Remedial Action. Reprint with Supplementary Insert - Summer 1982.

Daily Precipitation Chemistry Listings and Statistical Summaries July 15, 1980 - December 31, 1981. APIOS 001/82. Summer 1982.

The Economics of Acid Precipitation: Ontario's Socio-economic Research Program. API 007/82. December 1982.

Experimental Neutralization of a Small, Seasonally Acidic Stream Using Crushed Limestone. API 004/82. Summer 1982.

Lagrangian Model of the Long Range Transport of Sulphur Oxides. API 008/82. Fall 1982.

Monitoring of Lake Superior Tributaries, 1980-1981. API 009/82. Fall 1982.

An Overview: The Cumulative Wet/Dry Deposition Network. December 1982.

An Overview: The Event Wet/Dry Deposition Network. API 002/82. Summer 1982.

**1982 (continued)**

The Province of Ontario. Presentation to the Michigan Air Pollution Control Commission in Opposition to the Detroit Edison Request to Delay Bringing its Monroe Power Plant into Compliance with the State of Michigan "1% or Equivalent Sulphur in Fuel" Rule. Monroe, Michigan. June 30, 1982.

Report of the Ontario/Canada Task Force for the Development and Evaluation of Air Pollution Abatement Options for Inco Limited and Falconbridge Nickel Mines, Limited in the Regional Municipality of Sudbury, Ontario. December 21, 1982.

Standard Methods for National Wet-only Precipitation Sampling and Chemistry Analysis. N.R. McQuaker, P.D. Kluckner, J.E. Torneby, S.E. Sorba, W.H. Chan and M.E. Still. A Joint Report with the Federal and Other Provincial Governments. 1982.

A Synoptic Survey of the Acidity of Ground Waters in the Muskoka-Haliburton Area of Ontario, 1980. API 006/82. Fall 1982.

A Synoptic Survey of the Acidity of Ground Waters in the Sudbury Area of Ontario, 1981. API 005/82. Fall 1982.

**1981**

Acid Sensitivity Survey of Lakes in Ontario. API 002/81. March 1981.

An Annotated Bibliography: Terrestrial Effects of Acidic Precipitation. APIOS 003/81. July 1981.

Chemical, Microbiological and Physical Interactions of Acidic Precipitation Within a Lake and its Drainage Basin. R.J. Flett. API 004/81. July 1981.

An Intercomparison Study of Three Precipitation Sampling Networks in Ontario - APIOS, CANSAP and GLPN. R.J. Vet, W.H. Chan and M.A. Lusis. Report No. ARB-002-91-ARSP. September 1981.

Lakewide Odours in Ontario and New Hampshire Caused by Chrysochromulina Breviturrita Nich. (Prymnesiophyceae). API 001/81. 1981.

Ontario Ministry of the Environment. Studies of Lakes and Watersheds Near Sudbury, Ontario: Final Limnology Report of the Sudbury Environmental Study: Volume I.

Ontario Ministry of the Environment. Studies of Lakes and Watersheds Near Sudbury, Ontario: Final Limnology Report of the Sudbury Environmental Study: Volume II. Appendices.

1981 (continued)

The Province of Ontario. Presentation to the Air Pollution Control Board of the State of Indiana in Opposition to the Indiana-Kentucky Electric Generating Station Petition to Operate With an Increase in its Sulphur Dioxide Emissions to 7.52 pounds of $SO_2$ per Million BTU's of Heat Input. Indianapolis, Indiana. October 7, 1981.

The Province of Ontario. A Submission to the United States Environmental Protection Agency Hearing on Interstate Pollution Abatement. Washington, D.C. June 19, 1981.

The Province of Ontario. A Submission to the United States Environmental Protection Agency on Interstate Pollution Abatement. December 1981. Docket No. A-81-09.

The Province of Ontario. A Submission to the United States Environmental Protection Agency Opposing Relaxation of $SO_2$ Emission Limits in State Implementation Plans and Urging Enforcement. March 12, 1981. Expanded March 27, 1981.

The Seasonal Dependence of Atmospheric Deposition and Chemical Transformation Rates for Sulphur and Nitrogen Compounds. M.A. Lusis and L. Shenfeld. Report No. ARB-018-ARSP. 1981.

Simple Nitrogen Oxides Chemistry for Incorporation into Long Range Mathematical Models. Prepared by Concord Scientific Corporation. Report No. ARB-008-81-ARSP. February 1981.

1980

Acidic Precipitation in South-Central Ontario: Analysis of Source Regions Using Air Parcel Trajectories. J. Kurtz and W. Scheider. MOE Report, May 1980.

Bulk Deposition in the Sudbury and Muskoka-Haliburton Areas of Ontario During the Shutdown of Inco Ltd. in Sudbury. W.A. Scheider, D.S. Jeffries and P.J. Dillon. May 1980.

The Case Against the Rain: A Report on Acidic Precipitation and Ontario Programs for Remedial Action. October 1980.

Precipitation Sampler Comparative Study. Report Number ARB-007-81-ARSP. May 1980.

1979

Ontario Ministry of the Environment. Determination of the Susceptibility to Acidification of Poorly Buffered Surface Waters. Ont. Min. Environ. Tech. Rep., 21 p.

**1979** (continued)

Survival of Rainbow Trout, *Salmo Gairdneri* in Submerged Enclosures in Lakes Treated with Neutralizing Agents Near Sudbury, Ontario. N.D. Yan, R.E. Girard and C.L. Lafrance. Ont. Min. Environ. Tech. Rep. LTS 79-2, 29 p.

**1978**

Acid Precipitation: A Review. N.D. Yan. Tech. Rep. EE-9, 35 p.

## A.P.I.O.S. RELATED PUBLICATIONS/PAPERS

Bisessar, S., K.T. Palmer, A.L. Kuja and S.N. Linzon. (1984). Influence of Simulated Acidic Rain on Bacterial Speck of Tomato. *Journal of Environmental Quality*, Vol. 13, pp. 18-22.

Chan, W.H. Quality Assurance - Monitoring of Wet Deposition. Presented at the *Symposium on Monitoring and Assessment of Airborne Pollutants with Special Emphasis on Long-Range Transport and Deposition of Acidic Materials*, National Research Council of Canada, Ottawa, Ontario, August 30-September 1, 1982.

Chan, W.H. (1982). Sudbury Environmental Study - Atmospheric Research Program. Report ARB-27-82-ARSP.

Chan, W.H. and M.A. Lusis. (1983). Sudbury Smelter Emissions and Their Fate in the Atmosphere. Submitted to *Environmental Science and Technology* as a feature article.

Chan, W.H., M.A. Lusis, R.D.S. Stevens and R.J. Vet. (1984). A Precipitation Sampler Intercomparison. *Water, Air and Soil Pollution*, 23:1-13.

Chan, W.H., C.U. Ro, R.J. Vet, A.J.S. Tang and M.A. Lusis. Precipitation Scavenging and Dry Deposition of Pollutants from the Inco Nickel Smelter in Sudbury. *Proceedings of the 4th International Conference on Precipitation Scavenging, Dry Deposition and Resuspension*, Ed. G. Slinn, Elsevier Science Publishing Co. Inc., 1983.

Chan, W.H., A.J. Tang and M.A. Lusis. (1983). Precipitation Concentration and Wet Deposition Fields of Pollutants In Ontario, 1981. Report ARB-61-83-ARSP.

Chan, W.H., R.J. Vet, M.A. Lusis and G.B. Skelton. (1983). Airborne Particulate Size Distribution Measurements in Nickel Smelter Plumes. *Atmospheric Environment*, 17:1173-1181.

Chan, W.H., R.J. Vet, M.A. Lusis and G.B. Skelton. (1982). Size Distribution and Emission Rate Measurements of Particulate in the Inco 381 M Chimney and Iron Ore Recovery Plant Stack Plumes, 1979-80. Report ARB-TDA-62-80.

Chan, W.H., R.J. Vet, C.U. Ro, M.A. Lusis. (1982). Impact of the Inco Nickel Smelter Emissions on Precipitation Quality in the Sudbury Area. *Atmospheric Environment*, 16:801-814.

Chan, W.H., R.J. Vet, C.U. Ro, A.J.S. Tang and M.A. Lusis. (1982). An Analysis of the Impact of Smelter Emissions on Atmospheric Dry Deposition in the Sudbury Area: Sudbury Environmental Study Airborne Particulate Matter Network Results. Report ARB-012-81-ARSP.

Chan, W.H., R.J. Vet, C.U. Ro, A.J.S. Tang and M.A. Lusis. (1982). An Analysis of the Impact of Smelter Emissions on Precipitation Quality and Wet Deposition in the Sudbury Area: Sudbury Environmental Study Event Precipitation Network Results. Report ARB-05-82-ARSP.

Chan, W.H., R.J. Vet, C.U. Ro, A.J.S. Tang and M.A. Lusis. (1984). Impact of Inco Smelter Emissions on Wet And Dry Deposition in the Sudbury Area. *Atmospheric Environment*, 18:1001-1008.

Chan, W.H., R.J. Vet, C.U. Ro, A.J.S. Tang and M.A. Lusis. (1984). Impact of Smelting Activities on Long-Term Precipitation Quality and Wet Deposition Fields in the Sudbury Basin. *Atmospheric Environment*, 18:1175-1188.

Chan, W.H., R.J. Vet, C.U. Ro, A.J.S. Tang and M.A. Lusis. (1982). Precipitation Quality and Wet Deposition in the Sudbury Basin: Sudbury Environmental Study Cumulative Precipitation Network Results. Report ARB-04-82-ARSP.

Chan, W.H., R.J. Vet, G.B. Skelton and M.A. Lusis. (1982). Size Distribution and Emission Rate Measurements of Particulates in the 93 M Falconbridge Smelter Stack Plume, 1979. Report ARB-TDA-57-80.

Clark, K.L. and R.J. Hall. (1985). Effects of Elevated Hydrogen Ion and Aluminum on Survival of Amphibian Embryos and Larvae. *Can. J. Zool.* 63:116-123.

Clark, K.L. and B. LaZerte. (1985). A Laboratory Study of the Effects of Aluminum and pH on Amphibian Eggs and Tadpoles. *Can. J. Fish. Aquat. Sci.* (in press).

Conroy, N., K. Hawley, W. Keller and C. Lafrance. (1976). Influences of the Atmosphere on Lakes in the Sudbury Area. Proc. First Spec. Symp. on Atmospheric Assoc. *Great Lakes Res.* 2:146-165.

Conroy, N., K. Hawley and W. Keller. (1978). Extensive Monitoring of Lakes in the Greater Sudbury Area, 1974-76. Ontario Ministry of the Environment Technical Report. 40 pages plus appendices.

Conroy, N., D.S. Jeffries and J.R. Kramer. (1974). Acid Shield Lakes in the Sudbury, Ontario Region. *Proceedings of 9th Canadian Symposium on Water Pollution Research in Canada*, No. 9, pp. 45-61.

Conroy, N. and W. Keller. (1976). Geological Factors Affecting Biological Activity in Precambrian Shield Lakes. *Canadian Mineral* 14:62-72.

Craig, G.R. and W.F Baksi. (1977). The Effects of Depressed pH on Flagfish Reproduction, Growth and Survival. *Wat. Res.* 11:621-626.

Dillon, P.J. (1984). The Use of Mass Balances and Mass Balance Models for Quantification of the Effects of Anthropogenic Activities on Lakes Near Sudbury, Ontario. pp. 283-347, in *Environmental Impacts of Smelters*, J. Nriagu (ed.), Advances in Environmental Science Series, John Wiley and Sons, Inc.

Dillon, P.J. (1983). Chemical Alterations of Surface Waters by Acidic Deposition in Canada. *Wat. Qual. Bull.* 8:127-132.

Dillon, P.J. and R.D. Evans. (1982). Whole-lake Lead Burdens in Sediments of Lakes in Southern Ontario, Canada. *Hydrobiol.* 91:121-130.

Dillon, P.J., D.S. Jeffries and W.A. Scheider. (1982). The Use of Calibrated Lakes and Watersheds for Estimating Atmospheric Deposition Near a Large Point Source. *Wat. Air Soil Pollut.* 18:241-258.

Dillon, P.J., D.S. Jeffries, W.A. Scheider and N.D. Yan. (1980). Some Aspects of Acidification in Southern Ontario. p. 212-213, In *"Proc. Int. Conf. Ecol. Impact Acid Precip."*, D. Drablos and A. Tollan [eds.], Norway.

Dillon, P.J., D.S. Jeffries, W. Snyder, R. Reid, N.D. Yan, D. Evans, J. Moss and W.A. Scheider. (1978). Acidic Precipitation in South-Central Ontario: Recent Observations. *J. Fish. Res. Board. Can.* 35:809-815.

Dillon, P.J. and W.A. Scheider. (1984). Modelling the Reacidification Rates of Neutralized Lakes Near Sudbury, Ontario. pp. 121-154, in *Modelling of Total Acid Precipitation Impacts*, J.L. Schnoor (ed.), Acid Precipitation Series, Volume 9, Ann Arbor Science.

Dillon, P.J., P.J. Scholer and H.E. Evans. (1985). Lead-210 Fluxes in Acidified Lakes. *J. Environ. Geol. Wat. Sci.* (in press).

Dillon, P.J. and P.J. Smith. (1984). Trace Metal and Nutrient Accumulation in the Sediments of Lakes Near Sudbury, Ontario. pp. 375-426, in *Environmental Impact of Smelters*, J. Nriagu (ed.), Advances in Environmental Science Series, John Wiley and Sons, Inc.

Dillon, P.J., N.D. Yan and H.H. Harvey. (1984). Acidic Precipitation: Effects on Aquatic Ecosystems. *CRC Critical Reviews in Environmental Control*, 13:167-194.

Dillon, P.J., N.D. Yan, W.A. Scheider and N. Conroy. (1979). Acidic Lakes in Ontario, Canada: Characterization, Extent and Responses to Base and Nutrient Additions. *Arch. Hydrob. Beih, Ergebn. Limnol.* 13:317-336.

Ellenton, G., B.E. Ley and P.K. Misra. (1983). Treating Exponential Mass Decay When Wet Scavenging Varies Discreetly Within an Expanding Gaussian Dispersed Puff. The Meteorology of Acid Deposition, ed. P.J. Samson, *Proceedings of an APCA Specialty Conference*, pp. 528-536.

Evans, H.E., P.J. Smith and P.J. Dillon. (1983). Anthropogenic Zinc and Cadmium Burdens in Sediments of Selected Southern Ontario Lakes. *Can. J. Fish. Aquat. Sci.* 40:570-579.

Evans, R.D. and P.J. Dillon. (1982). Historical Changes in Anthropogenic Lead Fallout in Southern Ontario, Canada. *Hydrobiol.* 91:131-137.

Galloway, J.N. and P.J. Dillon. (1983). Effects of Acidic Deposition: The Importance of Nitrogen. *Ecological Effects of Acid Deposition.* Nat. Swedish Envir. Protection Bd. - Report PM 1636:145-160.

Glass, G.E. and T.G. Brydges. (1982). Problem Complexity in Predicting Impacts from Altered Precipitation Chemistry. In *Acid Rain/Fisheries*, R.E. Johnson (ed.), American Fisheries Society, Bethesda, Md., pp. 265-286.

Gunn, J.M. and W. Keller. (1985). Effects of Ice and Snow Cover on the Chemistry of Nearshore Lake Water During Spring Melt. *Annals of Glaciology* (in press).

Gunn, J.M. and W. Keller. (1981). Emergence and Survival of Lake Trout (Salvelinus namaycush) and Brook Trout (S. fontinalis) from Artificial Substrates in an Acid Lake. Ontario Fisheries Technical Report Series, 1, Toronto.

Gunn, J.M. and W. Keller. (1980). Enhancement of the Survival of Rainbow Trout (Salmo gairdneri) Eggs and Fry in an Acid Lake through Incubation in Limestone. *Can. J. Fish. Aquat. Sci.* 37:1522-1530.

Gunn, J.M. and W. Keller. (1984). In Situ Manipulation of Water Chemistry Using Crushed Limestone and Observed Effects on Fish. *Fisheries.* 9:19-24.

Gunn, J.M. and W. Keller. (1984). Spawning Site Water Chemistry and Lake Trout (Salvelinus namaycush) Sac Fry Survival During Spring Snowmelt. *Can. J. Fish. Aquat. Sci.* 42:319-329.

Harvey, H.H., R.C. Pierce, P.J. Dillon, J.P. Kramer and D.M. Whelpdale. (1981). Acidification in the Canadian Aquatic Environment. *Publ. NRCC No. 18475 of the Environment Secretariat*, National Research Council, Canada.

Hendry, G.R., N.D. Yan and K.J. Baumgartner. (1980). Responses of Freshwater Plants and Invertebrates to Acidification. pp. 457-466. In "Restoration of Lakes and Inland Waters". *Proc. Symp. 8-12 September 1980.* Portland, Maine, U.S.A. EPA 440 15-81-010.

Jeffries, D.S. (1984). Atmospheric Deposition of Pollutants in the Sudbury Area. pp. 117-154, in *Environmental Impacts of Smelters*, J. Nriagu (ed.), Advances in Environmental Impacts of Science Series, John Wiley and Sons, Inc.

Jeffries, D.S., C.M. Cox and P.J. Dillon. (1979). Depression of pH in Lakes and Streams in Central Ontario During Snowmelt. *J. Fish. Res. Board. Can.* 36:640-646.

Jeffries, D.S., W.A. Scheider and W.R. Snyder. (1984). Geochemical Interactions of Watersheds with Precipitation in Areas Affected by Smelter Emissions Near Sudbury, Ontario. pp. 195-241, in *Environmental Impacts of Smelters*, J. Nriagu (ed.), Advances in Environmental Science Series, John Wiley and Sons, Inc.

Jeffries, D.S. and W.R. Snyder. (1981). Atmospheric Deposition of Heavy Metals in Central Ontario. *Wat. Air Soil Pollut.* 15:127-152.

Jeffries, D.S. and W.R. Snyder. (1981). Variations in Chemical Composition of the Snowpack and Associated Melt-waters in Central Ontario. *Proc. 38th Eastern Snow Conference*, New York.

Jeffries, D.S., W.R. Snyder, W.A. Scheider and M. Kirby. (1978). Small-Scale Variations in Precipitation Loading Near Dorset, Ontario. *Wat. Poll. Res. Can.* 13:73-84.

Jeffries, D.S. and A.P. Zimmerman. (1980). Comments on the Analysis and Sampling of Low Conductivity Natural Waters for Alkalinity. *Can. J. Fish. Aquat. Sci.* 37:901-902.

Keller, W. (1978). Limnological Observations on the Aurora Trout Lakes. Ontario Ministry of the Environment Technical Report. 49 pages.

Keller, W. (1981). Planktonic Crustacea in Lakes in the Greater Sudbury Area. Ontario Ministry of the Environment Technical Report. 33 pages plus appendices.

Keller, W. (1983). Spring pH and Alkalinity Depressions in Lake Superior Tributaries. *J. Great Lakes Res.* 9:425-429.

Keller, W., J. Gunn and N. Conroy. (1980). Acidification Impacts on Lakes in the Sudbury, Ontario, Canada area. *Proc. Int. Conf. on the Ecological Impact of Acid Precipitation*, Sandefjord, Norway. pp. 228-229.

Keller, W. and J.R. Pitblado. (1984). Crustacean Plankton in Northeastern Ontario Lakes Subjected to Acidic Deposition. *Wat. Air Soil Poll.* 23:271-291.

Kuja, A.L. and A.J. Enyedi. (1983). Effect of Simulated Acid Rain on Agricultural Crops. *Proceedings Aarometeorological Workshop*, University of Guelph, pp. 82-83.

Kurtz, J. and W.A. Scheider. (1981). An Analysis of Acidic Precipitation in South-Central Ontario Using Air Parcel Trajectories. *Atm. Environ.* 15:1111-1116.

Kurtz, J., A.J. Tang, R.W. Kirk and W.H. Chan. (1983). Analysis of an Acidic Deposition Episode at Dorset Ontario. Accepted for publication in *Atmospheric Environment.*

LaZerte, B.D. (1984). Forms of Aqueous Aluminum in Acidified Catchments of Central Ontario: A Methodological Analysis. *Can. J. Fish. Aquat. Sci.* 41:766-776.

LaZerte, B.D. and P.J. Dillon. (1984). Relative Importance of Anthropogenic Versus Natural Sources of Acidity in Lakes and Streams of Central Ontario. *Can. J. Fish. Aquat. Sci.* 41:1664-1677.

Linzon, S.N., R.G. Pearson, W.I. Gizyn and M.A. Griffith. (1981). Terrestrial Effects of Long Range Pollutants on Crops and Soils. *Proceedings Air Pollution Control Association. Ontario and Québec Sections. Joint Meeting on Acid Deposition,* Montréal, Québec, 17 pp.

Linzon, S.N. and P.J. Temple. (1980). Soil Resampling and pH Measurements After an 18-Year Period in Ontario. *Proc. Int Conf. on the Ecological Impact of Acid Precipitation,* Sandefjord, Norway, pp. 176-177.

Lusis, M.A. Measurement Techniques for Acidic Airborne Constituents. *Presentation at the Symposium on Monitoring and Assessment of Airborne Pollutants with Special Emphasis on Long-Range Transport and Deposition of Acidic Materials,* National Research Council of Canada, Ottawa, Ontario, August 30-September 1, 1982.

Lusis, M.A., W.H. Chan, A.J. Tang and N.D. Johnson. Scavenging Rates of Sulphur and Trace Metals from a Smelter Plume. *Proceedings, 4th International Conference on Precipitation Scavenging, Dry Deposition and Resuspension.* E.G. Slinn, Elsevier Science Publishing Co. Inc. 1983.

Lusis, M.A., W.H. Chan, A.J. Tang and R.W. Kirk. (1983). Wet and Dry Deposition of Sulfur and Nitrogen Compounds on a Regional Scale: Results from the Ontario Network for 1982. *CACGP Symposium on Tropospheric Chemistry,* August 28 - September 3, Oxford.

Lusis, M.A. and L. Shenfeld. (1981). The Seasonal Dependence of Atmospheric Deposition and Chemical Transformation Rates for Sulphur and Nitrogen Compounds. Report No. ARB-08-ARSP.

McBean, E.A. and Associates Ltd. (1983). Linear Programming Screening Model for Development and Evaluation of Acid Rain Abatement Strategies. Toronto: Policy and Planning Branch, Ontario Ministry of the Environment.

McBean, E.A. and Associates Ltd. (1983). Linear Programming Screening Model for Development and Evaluation of Acid Rain Abatement Strategies. Appendix I: "Mathematical Model Documentation of DATAGEN". Toronto: Policy and Planning Branch, Ontario Ministry of the Environment.

McBean, E.A. and Associates Ltd. (1983). Linear Programming Screening Model for Development and Evaluation of Acid Rain Abatement Strategies. Appendix II: "Development of $SO_2$ Emission Control Costs". Toronto: Policy and Planning Branch, Ontario Ministry of the Environment.

McBean, E.A. and Associates Ltd. (1983). Linear Programming Screening Model for Development and Evaluation of Acid Rain Abatement Strategies. Appendix III: "Canadian Source Inventory". Toronto: Policy and Planning Branch, Ontario Ministry of the Environment.

McLaughlin, D.L., S.N. Linzon, D.E. Dimma and W.D. McIlveen. (1985). Sugar Maple Decline in Ontario. Interim Report, 18 pp.

McQuaker, N.R., P.D. Kluckner, J.E. Torneby, S. E. Sorba, W.H. Chan and M.E. Still. (1982). Standard Methods for National Wet-Only Precipitation Sampling and Chemical Analysis. A Joint Report with the Federal and other Provincial Governments.

Millan, M.M., S.C. Barton, N.D. Johnson, B. Weisman, M.A. Lusis, W. Chan and R. Vet. (1982). Rain Scavenging from Tall Stack Plumes: A New Experimental Approach. *Atmospheric Environment*, 16:2709-2714.

Miller, G.E., I. Wile and G. Hitchin. (1983). Patterns of Accumulation of Selected Metals in Members of the Soft-water Macrophyte Flora of Central Ontario Lakes. *Aquat. Botany*. 15:53-64.

Nicholls, K.H. (1978). Chrysochromulina breviturrita sp. nov., a New Freshwater Member of the Prymnesiophyceae. *J. Phycol.* 14:499-505.

Nicholls, K.H., J.L. Beaver and R.H. Estabrook. (1982). Lakewide Odours in Ontario and New Hampshire Associated with Chrysochromulina Breviturrita Nich. (Prymnesiophyceae). *Hydrobiol.*

Nicholls, K.H. and C. Cox. (1978). Atmospheric Nitrogen and Phosphorus Loading to Harp Lake, Ontario, Canada. *Water Resources Res:* 14:589-592.

Pitblado, J.R. and W. Keller. (1984). Data Report - Monitoring of Northeastern Ontario Lakes, 1981-83. Ontario Ministry of the Environment Technical Report. 9 pages plus appendices.

Pitblado, J.R., W. Keller and N. Conroy. (1980). A Classification and Description of some Northeastern Ontario Lakes Influenced by Acid Precipitation. *J. Great Lakes Res.* 6:247-257.

Ruby, S.M., J. Aezel and G.R. Craig. (1977). The Effects of Depressed pH on Oogenesis in Flagfish Jordanella floridae. *Wat. Res.* 11:757-762.

Ruby, S.M., J. Aezel an G.R. Craig. (1978). The Effects of Depressed pH on Spermatogenesis in Flagfish Jordanella floridae. *Wat. Res.* 12:621-626.

Scheider, W.A. (1984). Lake Water Budgets in Areas Affected by Smelting Practices Near Sudbury, Ontario. pp. 155-194, in *Environmental Impacts of Smelters*, J. Nriagu (ed.), Advances in Environmental Science Series, John Wiley and Sons, Inc.

Scheider, W.A. and T.G. Brydges. (1984). Whole-Lake Neutralization Experiments in Ontario: A Review. *Fisheries* 9:17-18.

Scheider, W.A. and P.J. Dillon. (1983). Predicting Chemical and Physical Effects of Acidic Deposition on Aquatic and Terrestrial Ecosystems - Information Needs. *Proc. Symp. Monitoring and Assessment of Airborne Pollutants.* Nat. Res. Council Canada. NRCC No. 20642:84-114.

Scheider, W.A., D.S. Jeffries and P.J. Dillon. (1981). Bulk Deposition in the Sudbury and Muskoka-Haliburton Areas of Ontario During the Shutdown of Inco Ltd., in Sudbury. *Atm. Environ.* 15:945-956.

Scheider, W.A., D.S. Jeffries and P.J. Dillon. (1979). Effects of Acidic Precipitation on Precambrian Freshwaters in Southern Ontario. *J. Great Lakes Res.* 5:45-51.

Scheider, W.A., B.A. Locke, A.C. Nicolls and R.E. Girard. (1985). Snowpack and Streamwater Chemistry in Three Watersheds in Muskoka-Haliburton, Ontario. *Proc. Can. Hydrology Symp.*, 10-12 June, 1984. Québec City, Québec (in press).

Scheider, W.A., L.A. Logan, H.S. Belore and R.C. MacRae. (1985). Simulation of Snowmelt and Streamflow During Spring Runoff in Muskoka-Haliburton, Ontario. *Proc. Can. Hydrology Symp.*, 10-12 June, 1984, Québec City, Québec (in press).

Scheider, W.A., L.A. Logan and M.G. Goebel. (1983). A Comparison of Two Models to Predict Snowmelt in Muskoka-Haliburton, Ontario. pp. 157-168, in *Proc. 40th Eastern Snow Conference*, June 2-3, 1983, Toronto.

Scheider, W.A., W.R. Snyder and B. Clark. (1979). Deposition of Nutrients and Ions by Precipitation in South-Central Ontario. *Wat. Air Soil Pollut.* 12:171-185.

Schiermeier, F.A. and P.K. Misra. (1983). Evaluation of Eight Linear Regional Scale Sulfur Models by the Regional Modelling Subgroup of the United States-Canada Memorandum of Intent Work Group 2. The Meteorology of Acid Deposition, Ed. P.J. Samson, *Proceedings of an APCA Specialty Conference*, pp. 330-345.

Seip, H.M. and P.J. Dillon. (1984). Acid Rain and Soil Chemistry. *Science* 225:1425-1426.

Seip, H.M., R. Seip, P.J. Dillon and E. de Grosbois. (1985). Model of Sulphate Concentration in a Small Stream in the Harp Lake Catchment, Ontario. *Can. J. Fish. Aquat. Sci.* (in press).

Suns, K., C. Curry and D. Russell. (1980). Effects of Water Quality and Morphometric Parameters on Mercury Uptake by Yearling Yellow Perch. OME Tech. Rep. LTS 80-1, 16 pp.

Tung, G., A. L. Kuja and S.N. Linzon. (1982). Histopathology of Plant Leaf Injury Caused by Simulated Acid Rain. *Proceedings of Microscopical Society of Canada*, Vol. IX, Univ. Alberta, pp. 64-65.

Venkatram, A. (1982). Short Range Short-term Fumigation Model for the Inco Superstack. Report #SES 013/82.

Venkatram, A., B. Ley and S.Y. Wong. (1982). A Statistical Model to Estimate Long-Term Concentrations of Pollutants Associated with Long-Range Transport and its Application to Emissions from the Sudbury Region. Report #ARB-36-81-SES.

Vet, R.J., W.H. Chan and M.A. Lusis. (1981). An Intercomparison Study of Three Sampling Networks in Ontario - APIOS, CANSAP and GLPN. Report No. ARB-002-81-ARSP.

Wile, I., G.E. Miller, G.G Hitchin and N.D. Yan. (1985). Species Composition and Biomass of the Macrophyte Vegetation of One Acidified and Two Acid Sensitive Lakes in Ontario. *Can. Field Nat.* (in press).

Wong, S.L. (1980). Algal Bioassays to Determine Toxicity of Metal Mixtures. *Hydrobiol.* 74:199-208.

Wright, R.F., N. Conroy, W.T. Dickson, R. Harriman, A. Henricksen and C.L. Schofield. (1980). Acidified Lake Districts of the World: a Comparison of Water Chemistry of Lakes in Southern Norway, Southern Sweden, Southwestern Scotland, the Adirondack Mountains of New York and Southeastern Ontario. *Proc. Int. Conf. on the Ecological Impact of Acid Precipitation*, Sandefjord, Norway. pp. 377-379.

Yan, N.D. (1983). The Effects of Changes in pH on Transparency and Thermal Regimes of Lohi Lake, Near Sudbury, Ontario. *Can. J. Fish. Aquat. Sci.*, 40:621-626.

Yan, N.D. (1980). Acid Rain: A Progress Report. In C.L. Gulston (ed.). Perspectives in Natural Resources. *Symposium III:* Water. 6-8 November, 1980. Lindsay, Ont. pp. 95-114.

Yan, N.D. (1979). Phytoplankton of an Acidified Heavy Metal Contaminated Lake Near Sudbury, Ontario; 1973-1977. *Water Air Pollut.* 11:43-55.

Yan, N.D. and P.J. Dillon. (1984). Experimental Neutralization of Lakes Near Sudbury, Ontario. pp. 417-456, in *Environmental Impacts of Smelters*, J. Nriagu (ed.), Advances in Environmental Science Series, John Wiley and Sons, Inc.

Yan, N.D. and W. Geiling. (1985). Elevated Planktonic Rotifer Biomass in Acidified, Metal-Contaminated Lakes Near Sudbury, Ontario. *Hydrobiol.* 120:199-205.

Yan, N.D., R.E. Girard and C.L. Lafrance. (1979). Survival of Rainbow Trout, Salmo gairdneri in Submerged Enclosures in Lakes Treated with Neutralizing Agents near Sudbury, Ontario. OME Tech. Rep. LTS 79-2. 29 pp.

Yan, N.D. and C. Lafrance. (1984). Responses of Acidic Neutralized Lakes Near Sudbury, Ontario to Nutrient Enrichment. pp. 457-521, in *Environmental Impacts of Smelters*, J. Nriagu (ed.), Advances in Environmental Science Series, John Wiley and Sons, Inc.

Yan, N.D., C.J. Lafrance and G.G. Hitchin. (1982). Planktonic Fluctuations in a Fertilized, Acidic Lake: The Role of Invertebrate Predators. In *Proceedings of an International Symposium on Acidic Rain and Fishery Impacts on Northeastern North America".* Cornell Univ. Ithaca, N.Y., August 2-5, 1981, pp. 137-154.

Yan, N.D. and G.E. Miller. (1984). Effects of Deposition of Acids and Metals on Chemistry and Biology of Lakes Near Sudbury, Ontario. pp. 243-282, in *Environmental Impacts of Smelters*, J. Nriagu (ed.), Advances in Environmental Science Series, John Wiley and Sons, Inc.

Yan, N.D., G.E. Miller, I. Wile and G.G. Hitchin. (1985). Richness of Aquatic Macrophyte Floras of Soft Water Lakes of Differing pH and Trace Metal Content in Ontario, Canada. *Aquatic Botany* (in press).

Yan, N.D., R.W. Nero, W. Keller and D.C. Lasenby. (1985). Are Chaoborus Larvae More Abundant in Acidified Lakes in Central Canada? *Holartic Ecology* (in press).

Yan, N.D., W.A. Scheider and P.J. Dillon. (1977). Chemical and Biological Changes in Nelson Lake, Ontario, Following Experimental Elevation of Lake pH. *Wat. Pollut. Res. Can.* 12:213-231.

Yan, N.D. and P. Stokes. (1978). Phytoplankton of an Acidic Lake and its Responses to Experimental Alterations of pH. *Environ. Conservat.* 5:93-100.

Yan, N.D. and R. Strus. (1980). Crustacean Zooplankton Communities of Acidic, Metal-Contaminated Lakes Near Sudbury, Ontario. *Can. J. Fish. Aq. Sci.* 37:2282-2293.